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Vortex pinning and modulated microwave absorption in thin HTSC films

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Abstract

We present the results of the experimental and theoretical investigation of the modulated microwave absorptions (MMWA) in the $Bi_2Sr_2CaCu_2O_8$ thin film with columnar defects. The dependence of the MMWA hysteresis loop on the applied magnetic field and the modulation amplitude was studied. It is found that the hysteresis has unusual properties, in particular, (i) the amplitude falls down when the magnetic field increases whereas the critical current density is nearly constant; (ii) the hysteresis changes the sign when the modulation amplitude increases. These features can be explained if one takes into account that in thin superconducting films ($d \leqslant \lambda$) each vortex interacts with a limited number of pinning centers with a different coordination (gradient). We develop the theoretical model of the MMWA hysteresis in a thin superconductor with regard to these peculiarities. Five possible types of pinning centers are considered. It is shown that the vortices pinned on the centers of different type can make opposite contributions to MMWA. Good agreement between calculated theoretical curves and experimental data has been obtained.

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1. Introduction

Measurements of microwave absorption (MWA) in the type II superconductors has such advantages as high sensitivity and the possibility to set up a large variety of external conditions. They were often used for studying the vortex state properties in high-T_c superconductors (see, for example, [1–4]). In order to obtain information on vortex dynamics from the MWA measurements it is necessary to use the corresponding theoretical model describing the vortex behavior under the action of two magnetic fields: DC and microwave ones. The theoretical model of MWA of bulk superconductors has been developed in Refs. [3,4]. The model [4] is based on the assumption that the superconductor is in a critical state which is due to the applied field variation when it is slowly swept and modulated with the frequency ω_m ($\nu_m \simeq 10$–10^6 Hz). A vortex located in a potential well executes an oscillatory motion under the action of the microwave field of the frequency ω_1 ($\nu_1 \simeq 10^{10}$ Hz) near its equilibrium position. The currents induced by sweeping and modulated magnetic field determine the vortex equilibrium position in the potential well. As is shown in Ref. [3], if one assumes that the potential well is anharmonic, the parameters of the vortex motion are defined by its equilibrium position, and so the microwave power absorption is modulated with the frequency ω_m. In this case it is called *modulated* microwave absorption (MMWA). In the MMWA method the measured signal is proportional to the modulation depth of the microwave power dissipation. When the applied field

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